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CONSTRUCTION OF A FINE FUEL IGNITION FURNACE

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ABSTRACT

A furnace capable of producing either spontaneous or pilot ignition and measuring temperatures at which these ignitions occur has been designed and constructed for use in ignition studies of fine forest fuels. One-inch-long sections of conifer needles, grass stems and leaves, and rotten wood represent the type of fuels capable of being ignited and tested in this furnace. Time-temperature relations for the ignition process of various fuels may be determined by using a three-channel plotter on which thermocouple traces for temperatures of the ignition chamber and fuel sample are recorded.

Determinations of total heat-flux output of the furnace and various methods of heat transfer were determined for an airflow of 5 liters per minute; convective heating contributed 55.4 percent and radiative heating contributed 44.6 percent.

Studies to investigate the ignition properties of fine forest fuels required the design and fabrication of an ignition-producing heat source. A review of research that has been conducted on the ignition of cellulosic materials revealed that a variety of ignition-producing devices were used by previous workers. These devices varied widely as to type of heat source utilized and manner in which ignition was accomplished.

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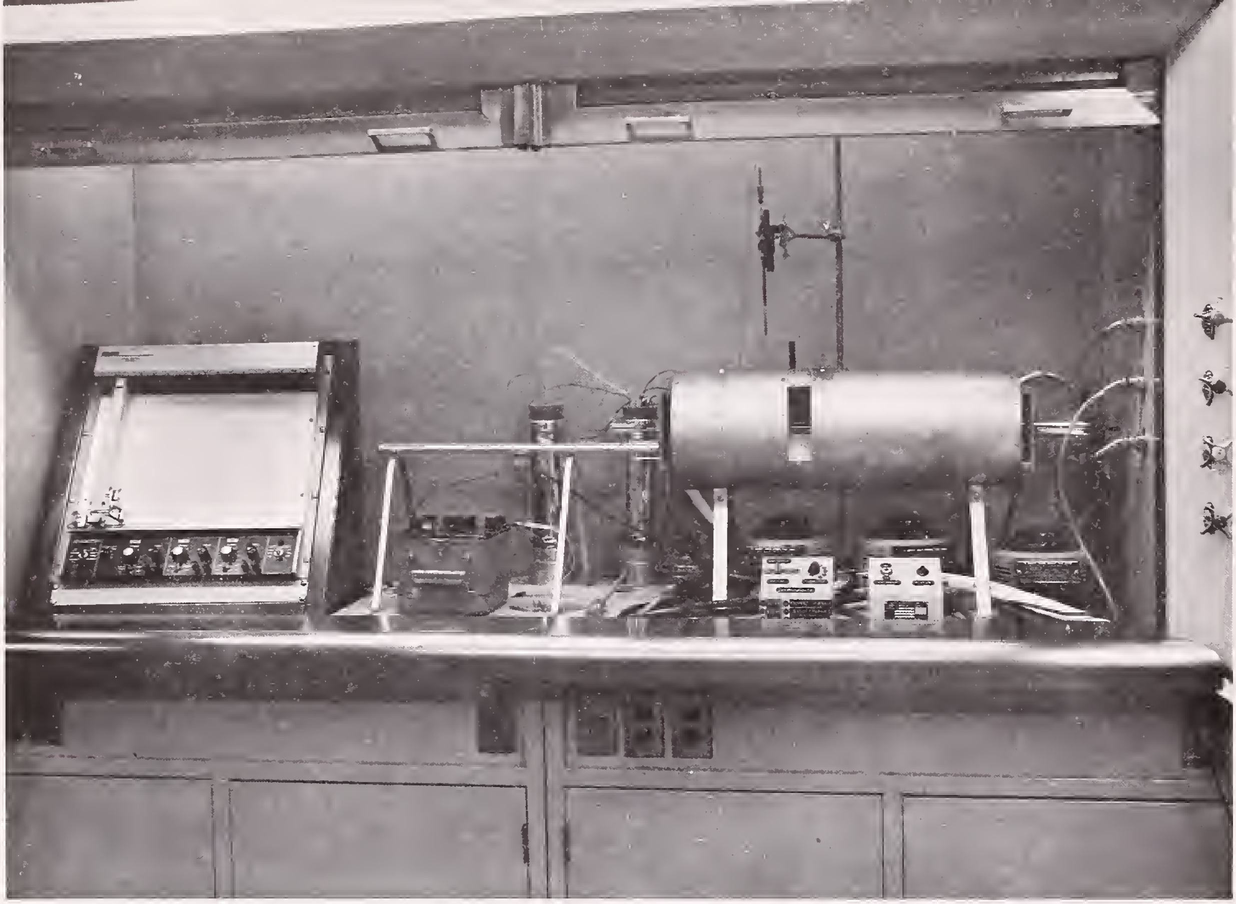

Figure 1.--Ignition furnace assembly.

Prince (1915) used an electric oven at various temperatures to drive volatiles from blocks of wood for ignition by a pilot flame. Doyle[2] and Space[3] used an electric hotplate as a heat source for their ignition studies. Wright (1932) used heated discs of metal dropped on the forest floor to determine ignition temperatures of forest floor duff. Brown[4] and VanKleeck[5] were two of the earlier workers who heated the sample in an airstream and attempted to measure the temperature of the sample at the time of ignition.

Early studies utilizing a radiative heat source were made in England by Lawson and Simms (1952). Also, the threat of possible use of thermonuclear weapons motivated a series of studies by Butler (1955), Martin (1958, 1959, 1963), Brown (1964), and others using a high-intensity carbon arc for ignition.

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[2] I. S. Doyle. The inflammability and fire holding properties of various wood rots at different moisture content. 1926. (Unpublished thesis on file at School of Forestry, Univ. Idaho, Moscow.)

[3] J. W. Space. The inflammability of various kinds of needle duff at different moisture contents. 1927. (Unpublished thesis on file at School of Forestry, Univ. Idaho, Moscow.)

[4] C. R. Brown. The determination of the ignition temperatures of solid materials. 1934. (Unpublished dissertation submitted to the faculty of the School of Eng., Catholic Univ. Amer., Wash., D.C.)

[5] A. VanKleeck. A preliminary study of ignition temperatures of finely chopped wood. 1936. (Unpublished report on file at Forest Products Laboratory, USDA Forest Serv., Madison, Wis.)

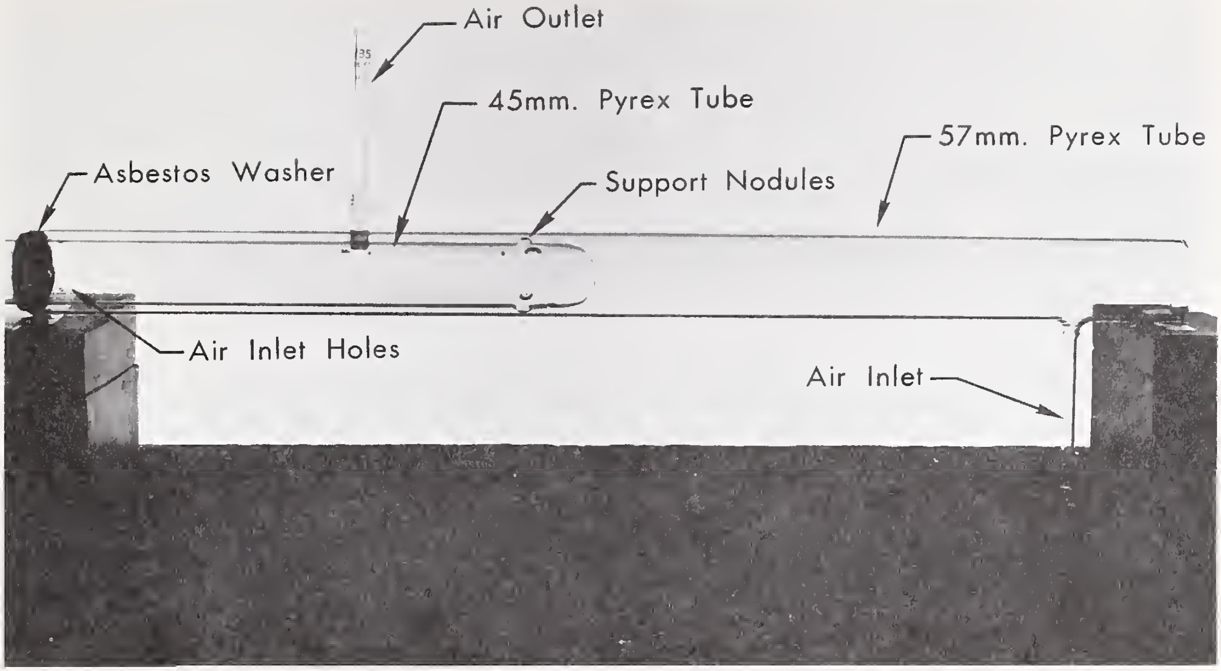

Figure 2.--Basic unit of ignition furnace.

VonDeichman (1960) and Mutch (1964) using a modified Jentzch ignition tester determined ignition time-temperature curves for various forest fuels that had been reduced to a common physical consistency.

Although extensive data have been reported in the literature, many of the reported results are inconclusive. The definition of ignition has varied widely in interpretation and the methods used to produce ignition have given widely diversified results. In addition, many of the studies have been theoretical in nature; while this has added to the knowledge, it has produced little of practical value.

A need has existed for an apparatus capable of igniting sections of wildland fuels under naturally occurring conditions. Since the relation between ignition time-temperature and heat intensity is highly dependent on the type of heat transfer mechanisms used to produce the ignition, this mechanism should be identified and quantified as precisely as possible. The researcher must know the proportions of heat transfer methods existing in the ignition device to correctly interpret test results. The apparatus also should be capable of producing and measuring temperatures for both spontaneous and pilot ignition.

A general view of the ignition furnace assembly is given in figure 1. The basic unit of the furnace consists of a 57 mm. O.D. Pyrex glass tube 32 inches long into which a 16-inch length of 45 mm. O.D. Pyrex glass tubing has been inserted, as shown in figure 2. The smaller tube was closed at one end and support nodules formed at four locations on this closed end before insertion into the larger tube. A washer was cut from 1/2-inch asbestos board to support the open end of the tube and to form a seal between the inner and outer tubes. Three holes 3/16-inch in diameter had previously been drilled

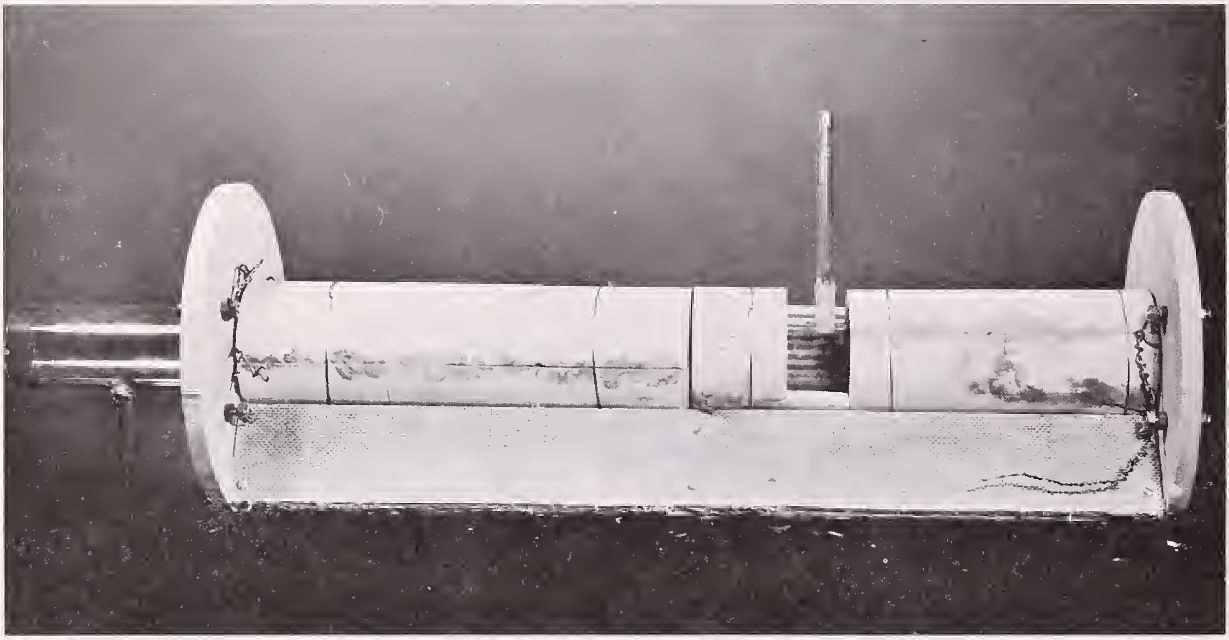

Figure 3.--Heater assembly of ignition furnace showing heating units, enclosed in ceramic, in place around the glass tube unit.

through the smaller tube at equidistant spacing on the circumference (figure 2). A number 10/30 ground-glass joint tube was fitted to the assembly by drilling holes of the proper size in both the inner and outer glass tubes a distance of 12 inches from the open ends of the tubes. The function of this ground-glass joint was to serve as an air outlet for the ignition chamber within the inner tube. An air inlet tube was then fused to the outer glass tube (figure 2).

Heat is supplied to the double tube assembly by three sets of Lindborg heating units (figure 3). Power to each set of units is controlled by a variable voltage transformer. The temperature of the tube assembly at each of the units is monitored by a 28-gage chromel-alumel thermocouple placed between the heating unit and the glass tube. The use of three separately controlled heating units provided a nearly constant temperature profile for the entire length of the furnace.

The entire tube and heater assembly was insulated with alumina wrap-around insulation (figure 4) with the exception of an observation port for the ignition chamber. The entire unit was covered with a sheet of 16-gage stainless steel fastened to the furnace assembly with No. 8 self-tapping screws (figure 5).

To insure adequate oxygen for combustion, compressed air is furnished the system through a flow meter; this air passes into the air inlet through a loosely-packed mass of stainless steel wool, and then flows through the 3/16-inch holes at the end of the smaller ignition tube assembly into the actual ignition chamber. The air is then exhausted through the ground-glass joint that is located directly above the ignition chamber.

The fuel sample is placed on an ignition boat assembly (figure 6) which is mounted on a slide mechanism to allow manual insertion into the ignition chamber. Insertion of this assembly into the chamber operates a microswitch that activates a three-channel

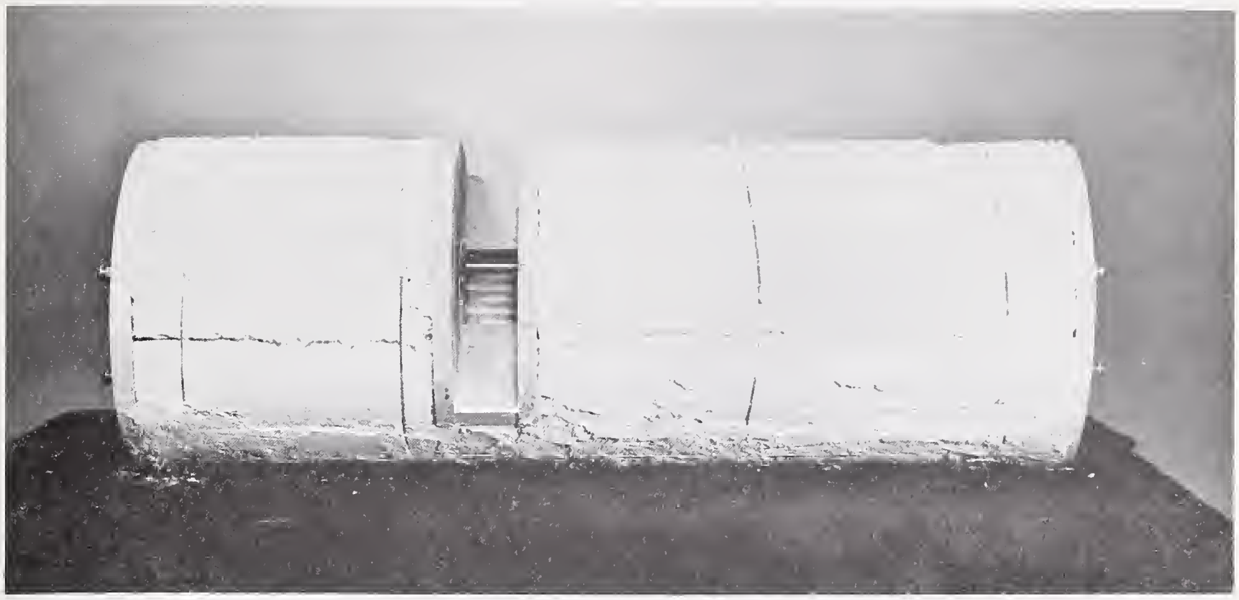

Figure 4.--Insulation of furnace tube and heater assembly.

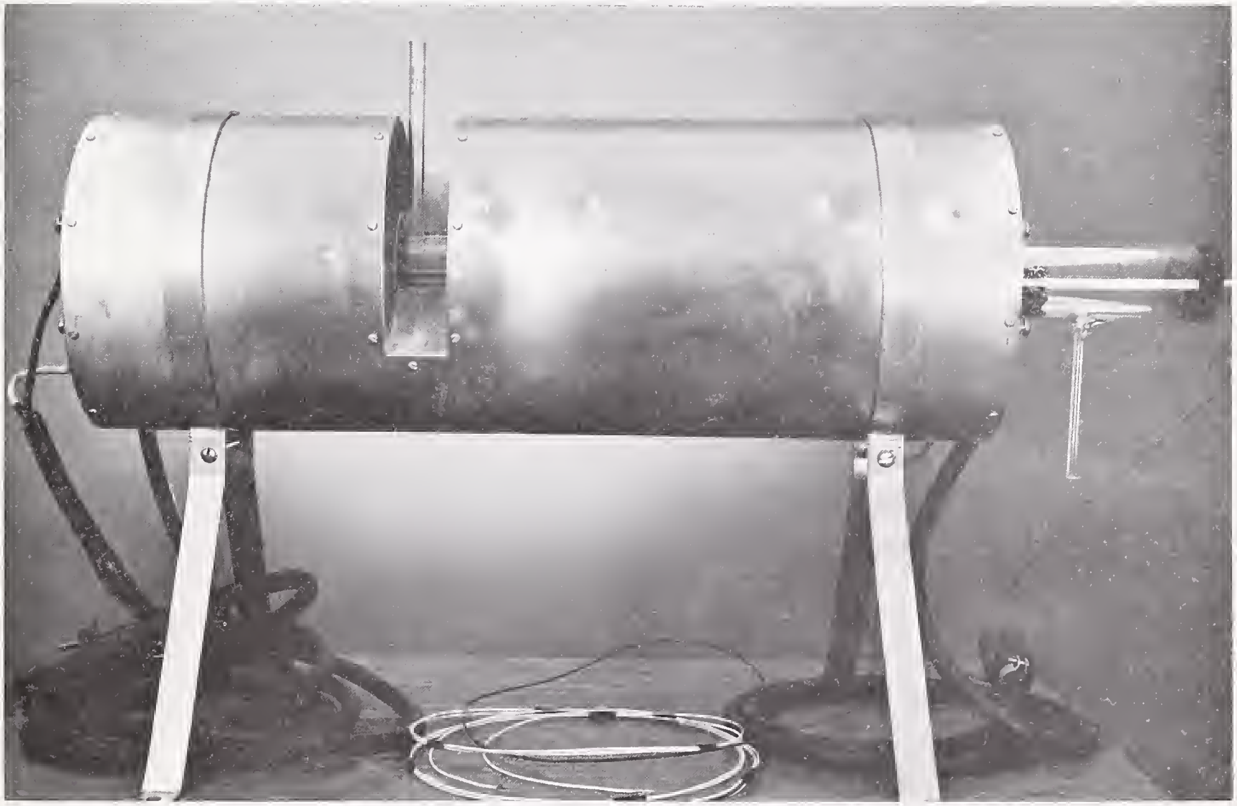

Figure 5.--Stainless steel covering and support assembly of furnace.

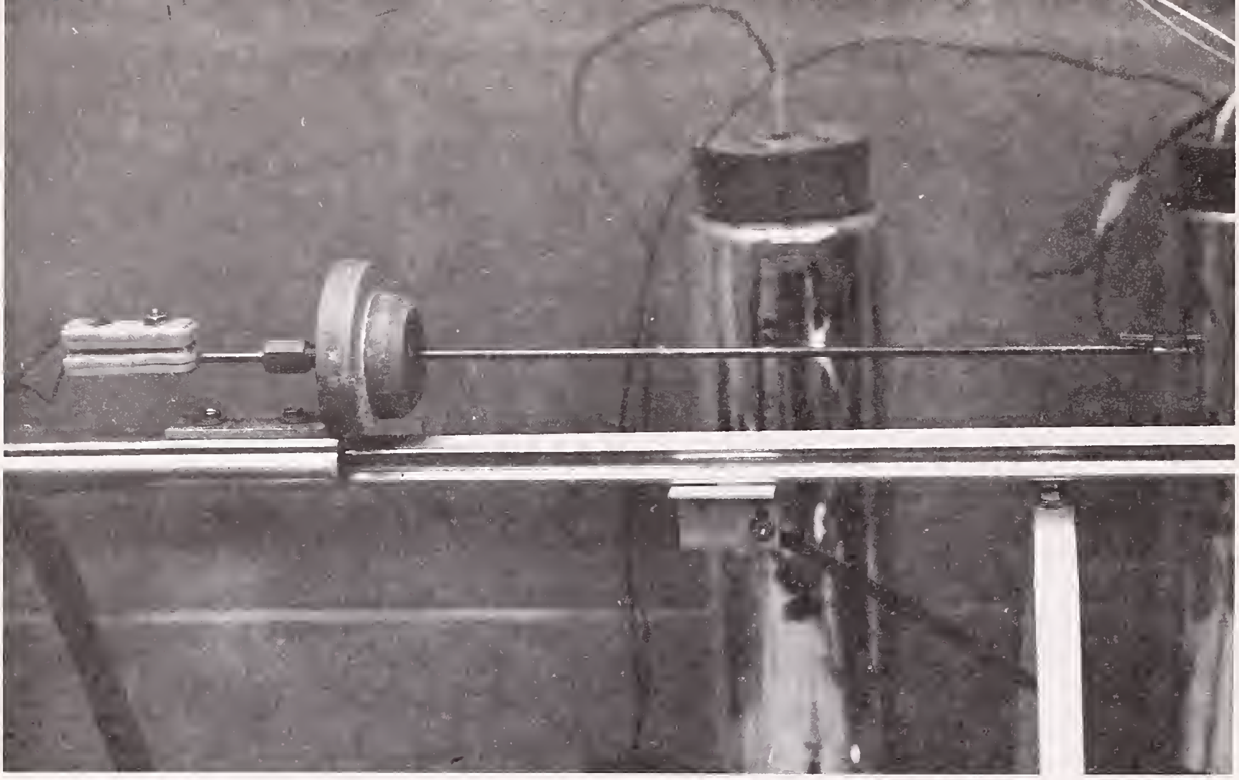

Figure 6.--Ignition boat assembly mounted on slide mechanism (thermocouple reference junctions are in background).

recorder. This recorder plots temperature of the ignition chamber and fuel sample's surface temperature against time. These two temperatures are obtained by two 0.003-inch chromel-alumel thermocouples on the ignition boat assembly (figure 7).

The necessary heat flux for producing spontaneous ignition is obtained by regulating the furnace temperature and volume of airflow. Pilot ignition is provided by inserting a small gas flame through the exhaust port into a position directly above the fuel sample being tested. This pilot flame is provided and accurately positioned by a hypodermic needle mounted on a modified microscope stage.

The entire ignition process may be observed through the furnace's observation port. An interrupter circuit to the recording pens marks the moment of glowing or flaming ignition. This allows comparison of visual identification of these points with the traces being recorded on the three-channel recorder.

The ignition boat assembly is designed to test small sections of forest fuels (figure 7). Trial-and-error testing has shown that a section of fuel approximately 1 inch in length and 1/8-inch in diameter is the optimum for a furnace of this size. Fuel sample dimensions are limited by the size of the ignition chamber. Conifer needles, grass stems and leaves, and sections of rotten wood have been tested in this furnace.

The types of heat transfer and total heat flux were determined for this furnace by using a 3/8-inch solid gold sphere instrumented with a thermocouple probe.[6] When using a constant airflow of 5 liters per minute the total heat flux input at the ignition chamber was 0.735 cal./cm.^{2}-sec. Of this amount, 55.4 percent was convective heating and 44.6 percent was radiative heating.

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[6] D. S. Stockstad. Gold spheres for heat flux determinations. 1968. (Unpublished data on file at Intermountain Forest and Range Exp. Sta., Northern Forest Fire Laboratory, Missoula, Montana.)

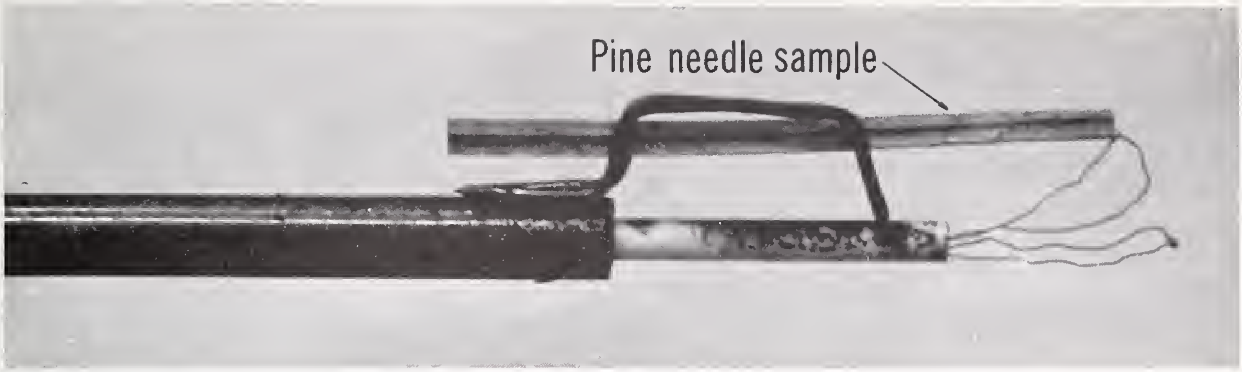

Figure 7.--Enlarged section of ignition boat with a 1-inch section of pine needle in test position. Note positions of air temperature thermocouple and surface temperature thermocouple.

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